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DeStefano et al.

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(54) **SYSTEM AND METHOD FOR PARSING, SUMMARIZING AND REPORTING LOG DATA**

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(51) **Int. Cl.**
G06F 17/30 (2006.01)

(52) **U.S. Cl.** **707/689**; 709/224; 709/203; 726/4; 726/11; 726/14; 707/999.003; 707/672; 707/662

(58) **Field of Classification Search** 709/224, 709/223, 221, 203; 707/3, 200, 1, 6, 7, 999.003, 707/689, 672, 662; 713/201; 726/3, 4, 11, 726/14

See application file for complete search history.

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2007/0011309 A1 * 1/2007 Brady et al. 709/224

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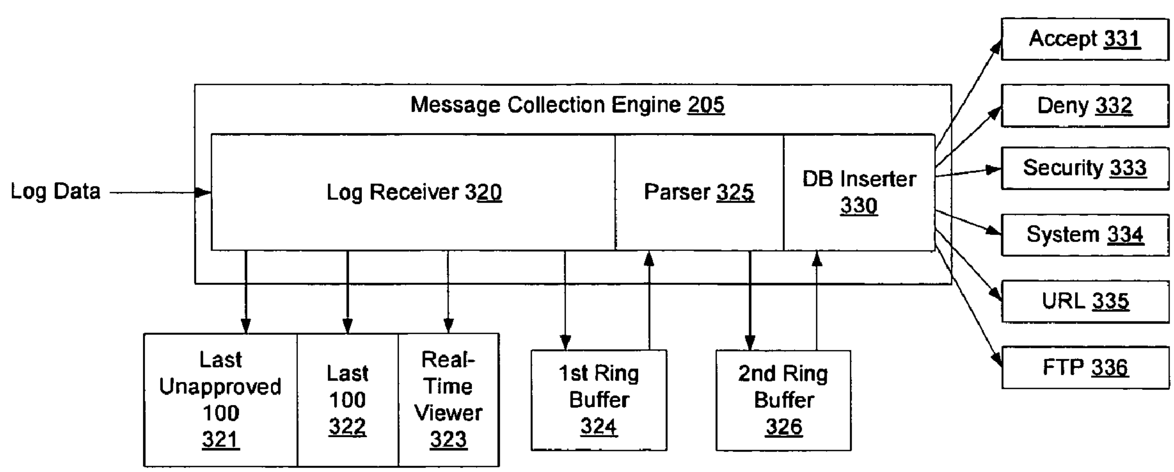
(74) *Attorney, Agent, or Firm* — Fish & Richardson P.C.

(57) **ABSTRACT**

A system and method is disclosed which enables network administrators and the like to quickly analyze the data produced by log-producing devices such as network firewalls and routers. Unlike systems of the prior art, the system disclosed herein automatically parses and summarizes log data before inserting it into one or more databases. This greatly reduces the volume of data stored in the database and permits database queries to be run and reports generated while many types of attempted breaches of network security are still in progress. Database maintenance may also be accomplished automatically by the system to delete or archive old log data.

18 Claims, 9 Drawing Sheets



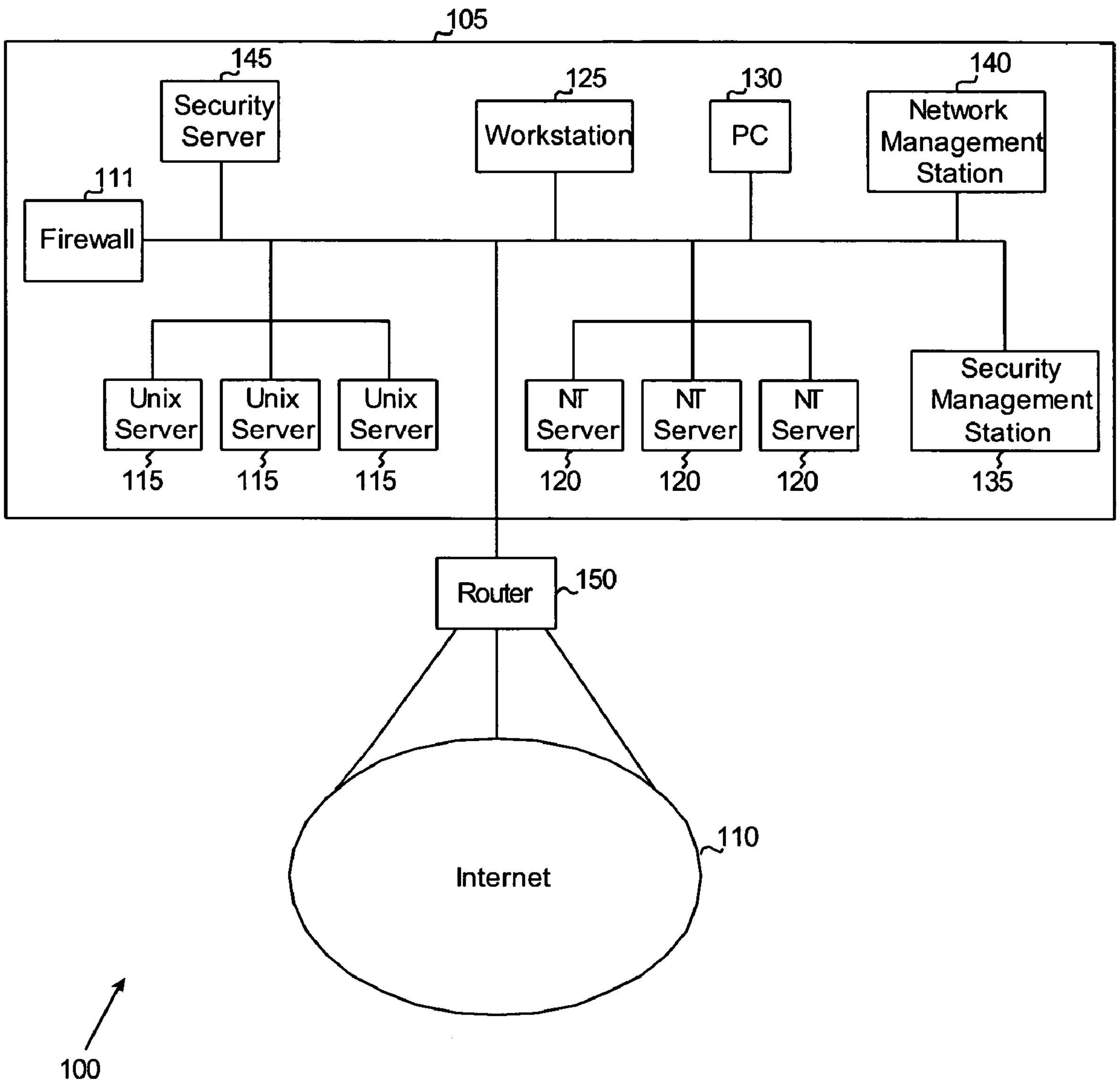

105
145
Security Server
125
Workstation
130
PC
140
Network Management Station
111
Firewall
Unix Server
Unix Server
Unix Server
115
115
115
NT Server
NT Server
NT Server
120
120
120
Security Management Station
135
Router
150
Internet
110
100

FIG. 1

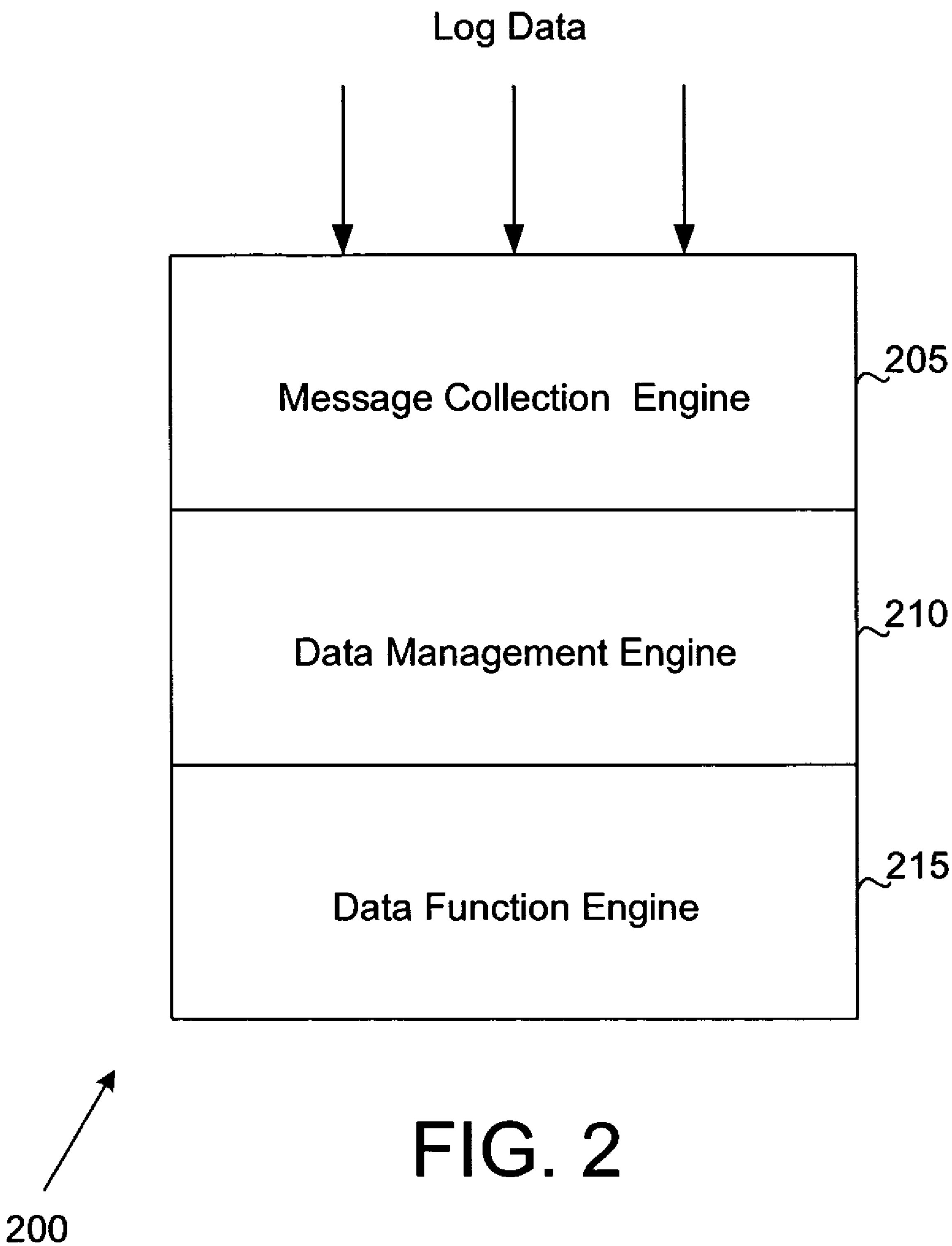

Log Data
Message Collection Engine
205
Data Management Engine
210
Data Function Engine
215
200

FIG. 2

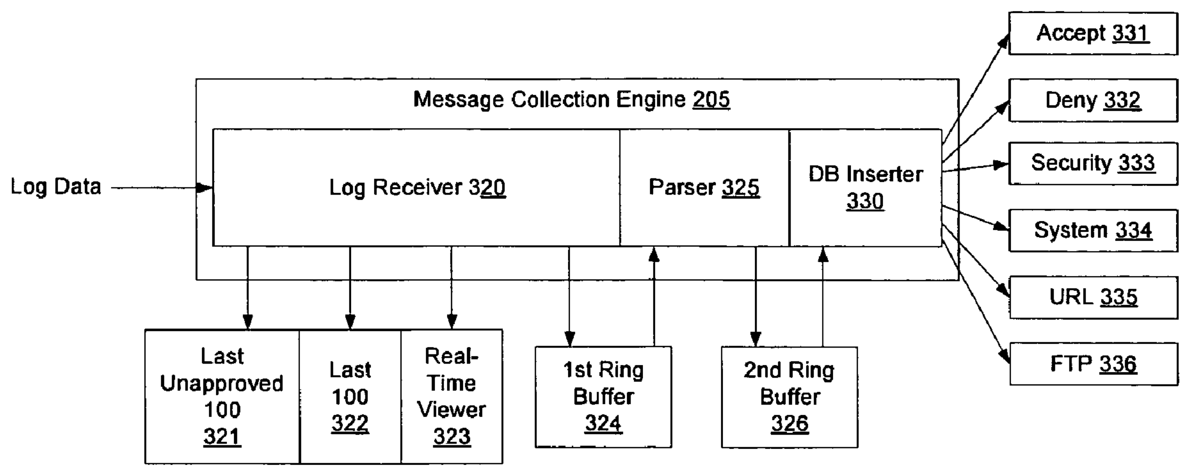

Message Collection Engine 205
Log Data
Log Receiver 320
Parser 325
DB Inserter 330
Accept 331
Deny 332
Security 333
System 334
URL 335
FTP 336
Last Unapproved 100 321
Last 100 322
Real-Time Viewer 323
1st Ring Buffer 324
2nd Ring Buffer 326

FIG. 3

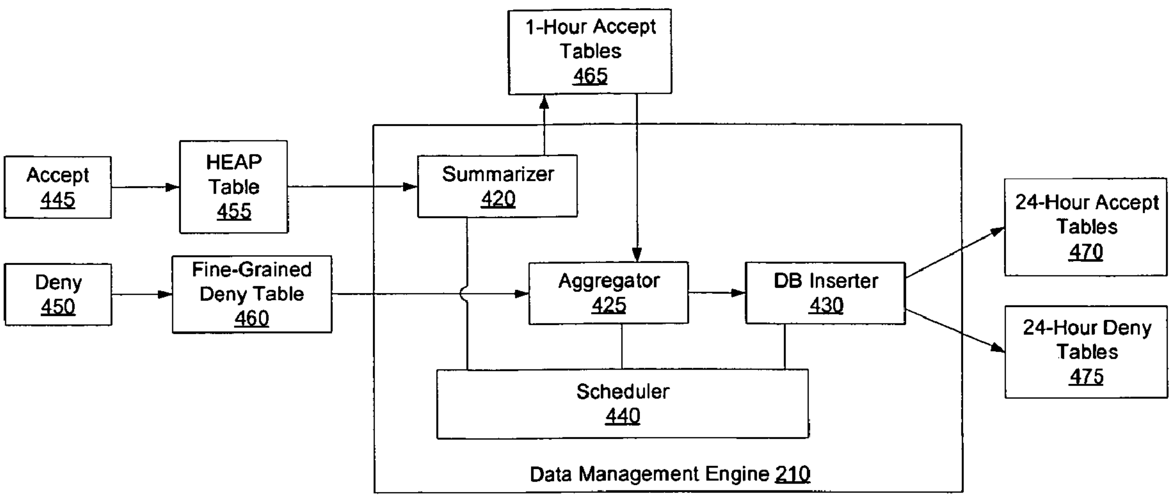

1-Hour Accept Tables 465
Accept 445
HEAP Table 455
Summarizer 420
Deny 450
Fine-Grained Deny Table 460
Aggregator 425
DB Inserter 430
24-Hour Accept Tables 470
24-Hour Deny Tables 475
Scheduler 440
Data Management Engine 210

FIG. 4

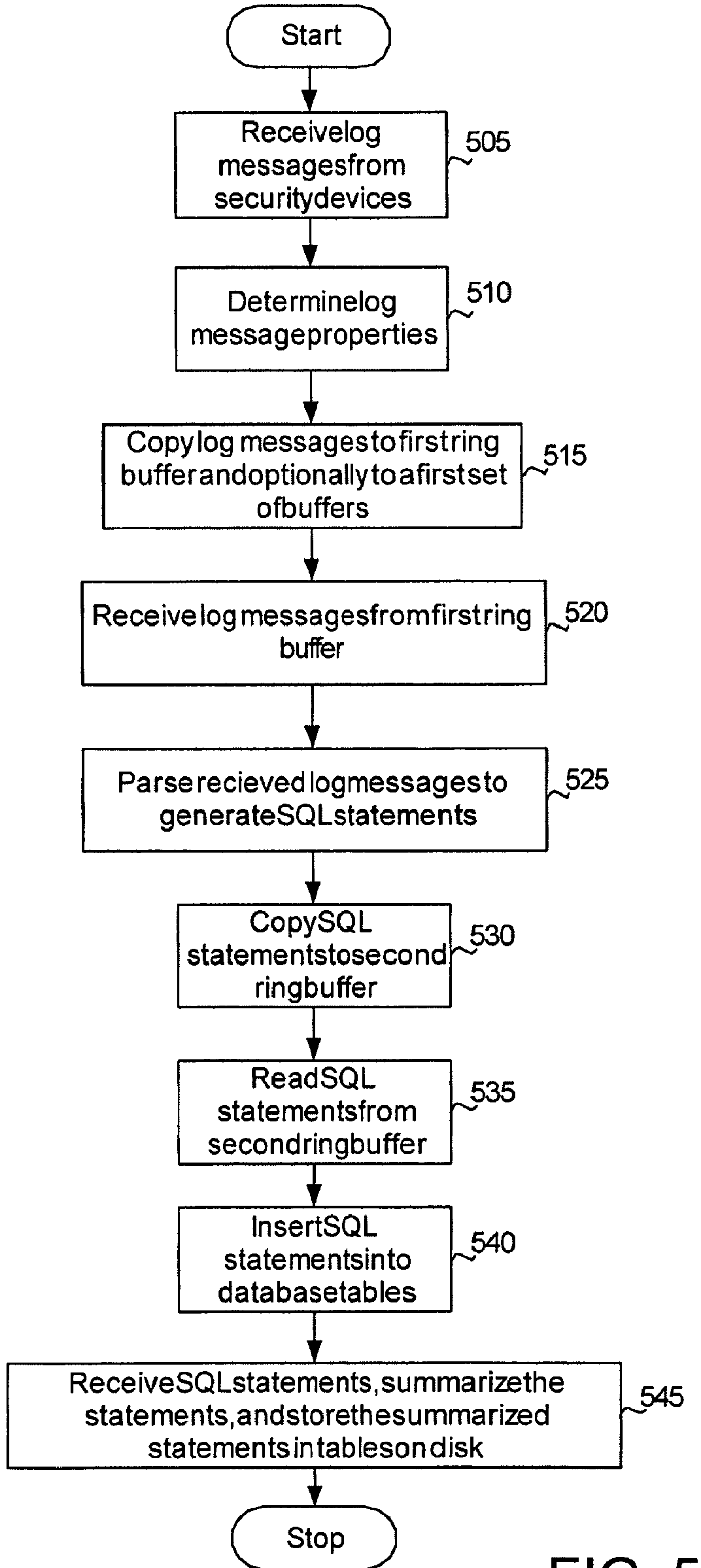

Start
Receivelog messagesfrom securitydevices
505
Determinelog messageproperties
510
Copylog messagestofirstring bufferandoptionallytoafirstset ofbuffers
515
Receivelogmessagesfromfirstring buffer
520
Parserecievedlogmessagesto generateSQLstatements
525
CopySQL statementstosecond ringbuffer
530
ReadSQL statementsfrom secondringbuffer
535
InsertSQL statementsinto databasetables
540
ReceiveSQLstatements,summarizethe statements,andstorethesummarized statementsintablesondisk
545
Stop

FIG. 5

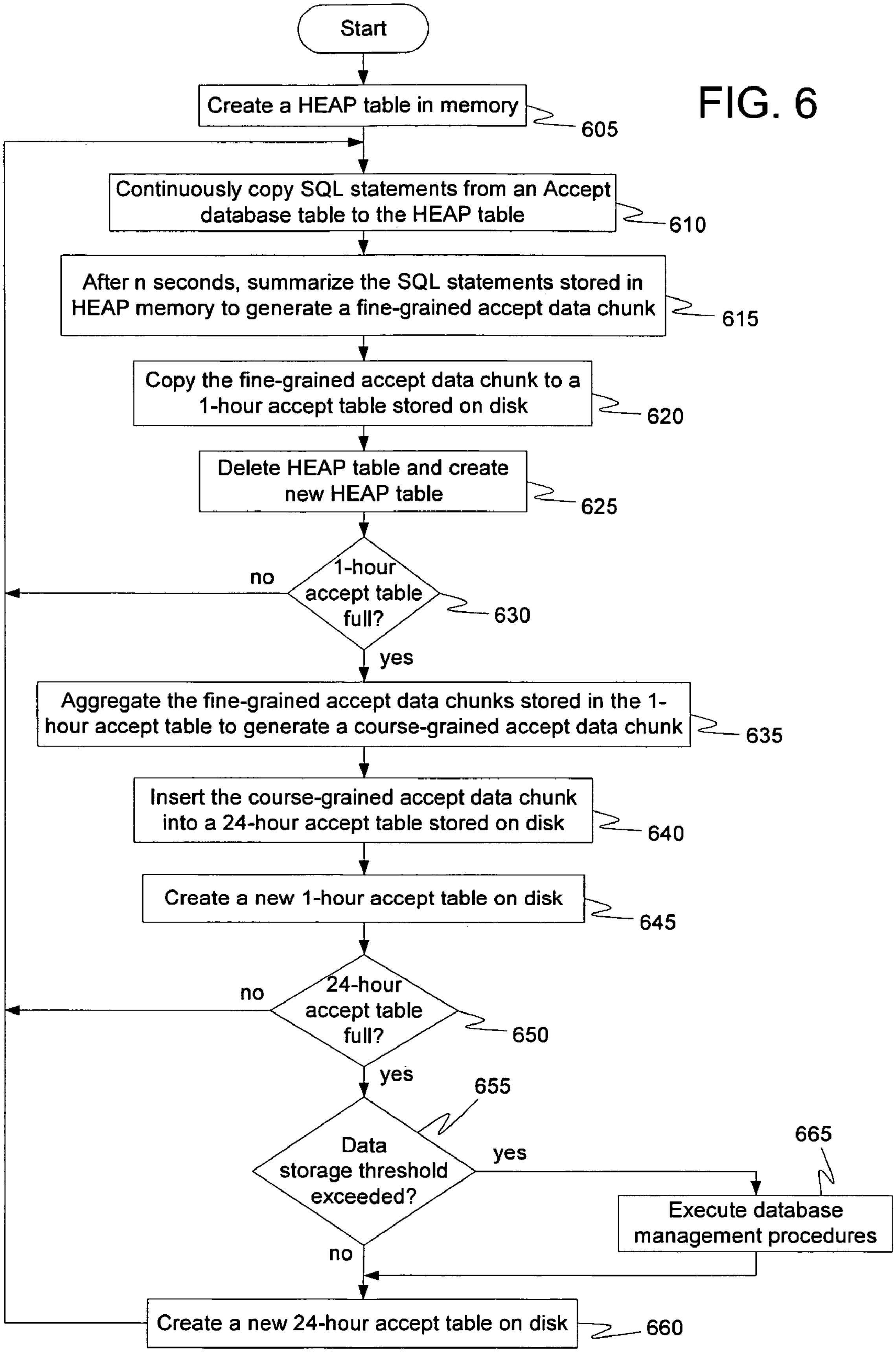
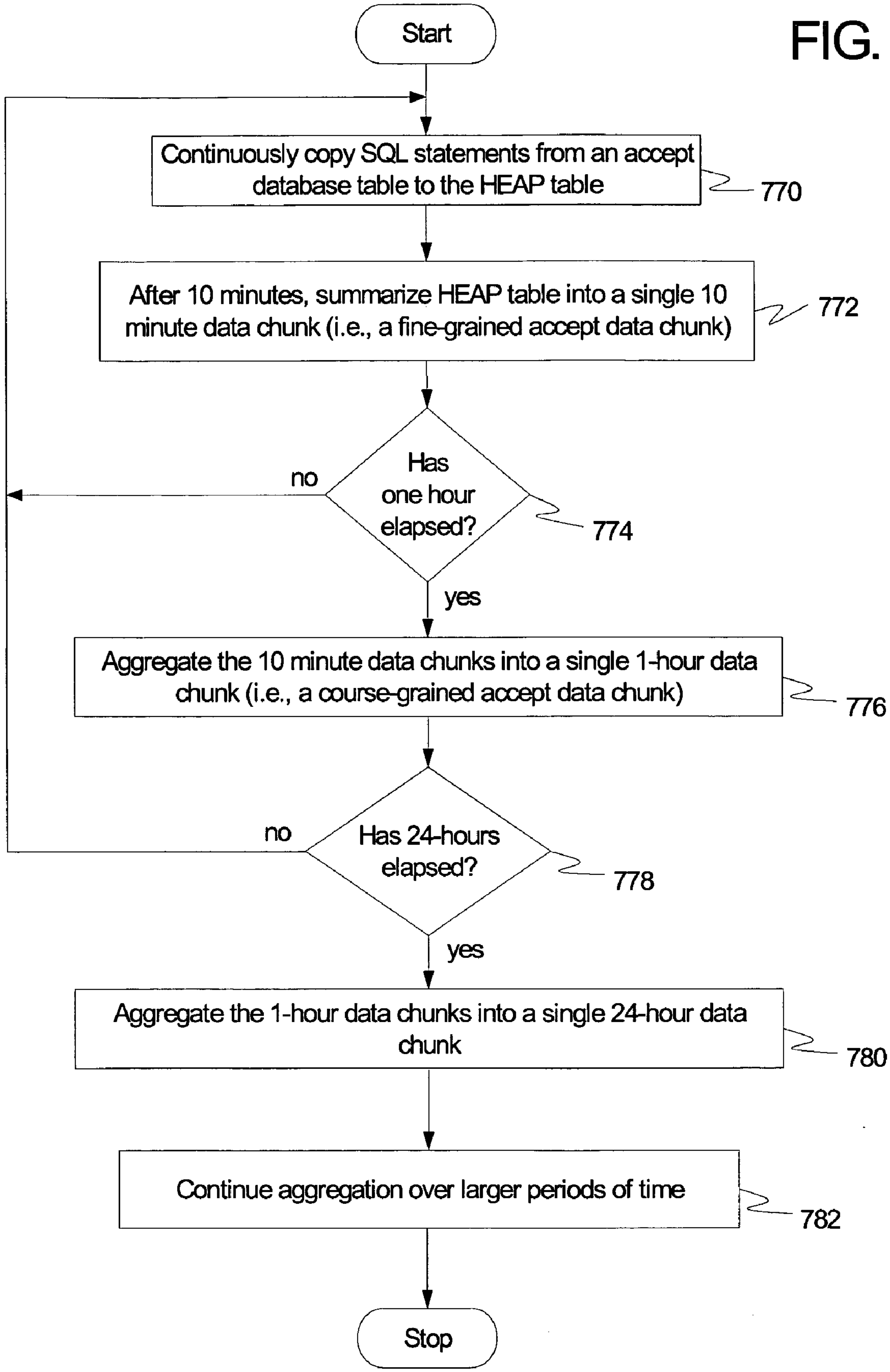

Start
Create a HEAP table in memory
605
Continuously copy SQL statements from an Accept database table to the HEAP table
610
After n seconds, summarize the SQL statements stored in HEAP memory to generate a fine-grained accept data chunk
615
Copy the fine-grained accept data chunk to a 1-hour accept table stored on disk
620
Delete HEAP table and create new HEAP table
625
1-hour accept table full?
no
yes
630
Aggregate the fine-grained accept data chunks stored in the 1-hour accept table to generate a course-grained accept data chunk
635
Insert the course-grained accept data chunk into a 24-hour accept table stored on disk
640
Create a new 1-hour accept table on disk
645
24-hour accept table full?
no
yes
650
Data storage threshold exceeded?
655
yes
no
Execute database management procedures
665
Create a new 24-hour accept table on disk
660

FIG. 6

FIG. 7


Start
Continuously copy SQL statements from an accept database table to the HEAP table
770
After 10 minutes, summarize HEAP table into a single 10 minute data chunk (i.e., a fine-grained accept data chunk)
772
Has one hour elapsed?
no
yes
774
Aggregate the 10 minute data chunks into a single 1-hour data chunk (i.e., a course-grained accept data chunk)
776
Has 24-hours elapsed?
no
yes
778
Aggregate the 1-hour data chunks into a single 24-hour data chunk
780
Continue aggregation over larger periods of time
782
Stop

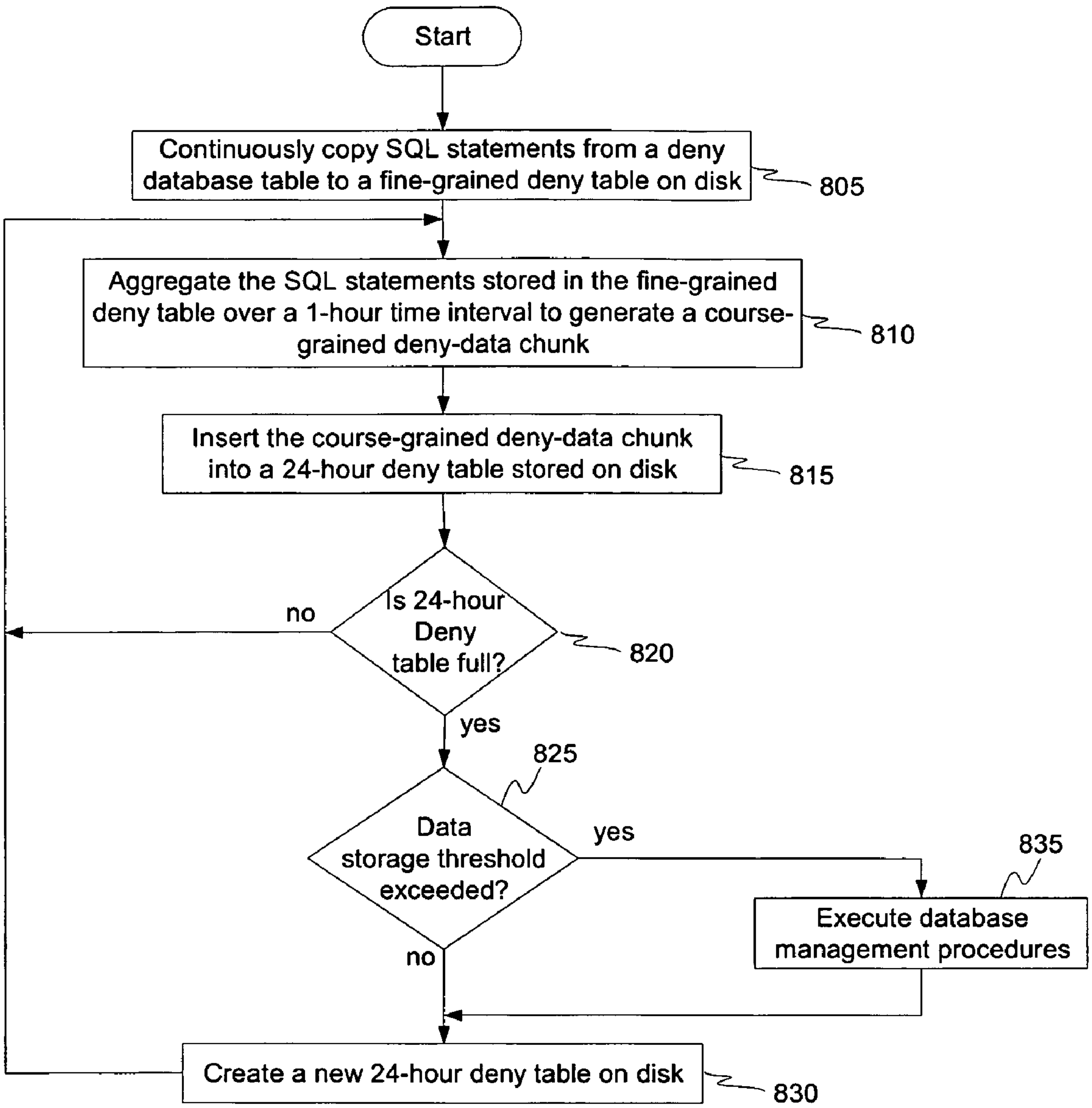

Start
Continuously copy SQL statements from a deny database table to a fine-grained deny table on disk
805
Aggregate the SQL statements stored in the fine-grained deny table over a 1-hour time interval to generate a course-grained deny-data chunk
810
Insert the course-grained deny-data chunk into a 24-hour deny table stored on disk
815
Is 24-hour Deny table full?
820
no
yes
825
Data storage threshold exceeded?
yes
no
835
Execute database management procedures
Create a new 24-hour deny table on disk
830

FIG. 8

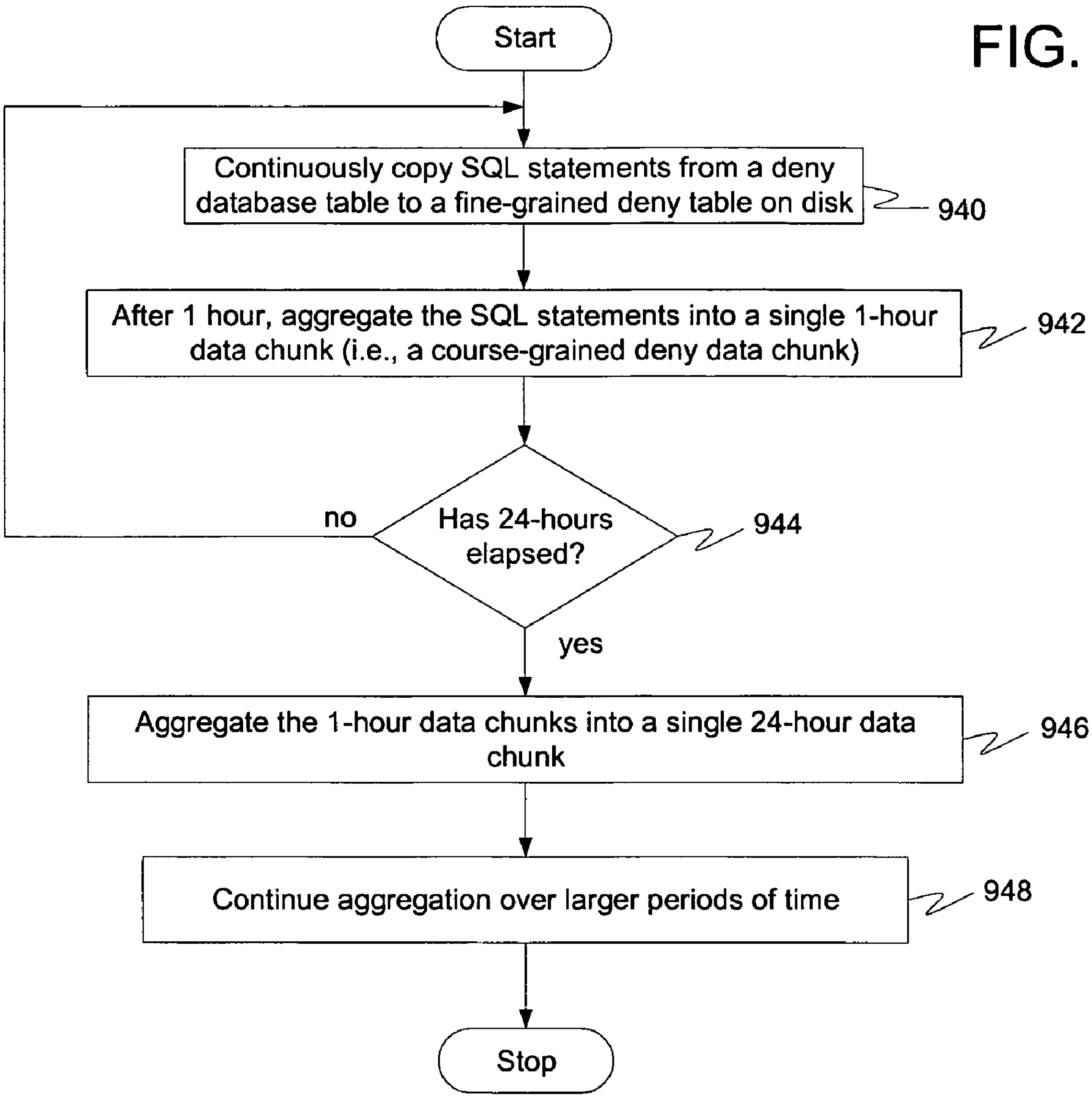

Start
Continuously copy SQL statements from a deny database table to a fine-grained deny table on disk
940
After 1 hour, aggregate the SQL statements into a single 1-hour data chunk (i.e., a course-grained deny data chunk)
942
Has 24-hours elapsed?
no
yes
944
Aggregate the 1-hour data chunks into a single 24-hour data chunk
946
Continue aggregation over larger periods of time
948
Stop

FIG. 9

SYSTEM AND METHOD FOR PARSING, SUMMARIZING AND REPORTING LOG DATA

RELATED APPLICATIONS

This application claims the benefit of co-pending U.S. provisional patent application Ser. No. 60/525,401 filed Nov. 26, 2003, entitled "System and Method for Summarizing Log Data" and co-pending U.S. provisional patent application Ser. No. 60/525,465 filed Nov. 26, 2003, entitled "System and Method for Parsing Log Data." The disclosures of both of these applications including their appendices are hereby incorporated by reference in their entireties.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates generally to computer network security and more particularly to a system and method for parsing, summarizing and reporting log data.

2. Description of the Related Art

Security devices such as network firewalls and routers act as data checkpoints that examine and block messages that do not meet specified device policies and security criteria. Network firewalls are frequently used to prevent unauthorized Internet users from accessing private networks connected to the Internet. Typically, all messages entering or leaving a private network, such as an intranet network, pass through a network firewall. The network firewall protects servers, workstations, personal computers, databases, storage devices, and other intranet-connected devices from virulent data, SPAM, and attempts to breech network security. Security schemes using network firewalls generally work well when network traffic is light to moderate. For example, attacks can usually be stopped using intrusion detection software. Later, security staff can manually review firewall log files to assure that proper remedies have been applied, and to gauge the effectiveness of the remedies.

However, as network performance increases and security attacks proliferate, a fundamental problem with network firewalls becomes manifest. A firewall may produce over 10 million various messages (i.e., log data) per day. If this data were printed as quickly as it was created, it would consume a ream of paper in less than 5 minutes. At high network speeds where multiple attacks can occur over a short period of time, existing firewall technology may generate such a large volume of raw log data that human review of the data after a security attack is nearly impossible. The amount of log data generated by security devices and vendors' consoles can quickly overwhelm a security staff, which may cause them to actually disable alarms that generate high volumes of messages. In many cases, the data is simply ignored or lost.

It would be desirable to provide a system and method to capture security log data, analyze it, and report attack information quickly, so that proper security remedies may be applied in a timely manner.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram of an exemplary network, in which an embodiment of the present invention may be implemented;

FIG. **2** illustrates an exemplary security platform, according to one embodiment of the present invention;

FIG. **3** illustrates the message collection engine of FIG. **2**, according to one embodiment of the present invention;

FIG. **4** illustrates the data management engine of FIG. **2**, according to one embodiment of the present invention;

FIG. **5** is a flowchart of exemplary method steps for parsing the log data as implemented by the message collection engine of FIG. **3**, according to one embodiment of the present invention;

FIG. **6** is an exemplary flowchart of method steps for summarizing the log data stored in the accept database table of FIG. **3**, according to one embodiment of the present invention;

FIG. **7** is an exemplary flowchart of method steps for summarizing the log data stored in the accept database table of FIG. **3**, according to another embodiment of the present invention;

FIG. **8** is an exemplary flowchart of method steps for aggregating log data stored in the deny database table of FIG. **3**, according to one embodiment of the present invention; and,

FIG. **9** is an exemplary flowchart of method steps for summarizing the log data stored in the deny database table of FIG. **3**, according to another embodiment of the present invention.

DETAILED DESCRIPTION

Security Administrators need to be able to capture all security log data and have a means to summarize and report attack information quickly so that proper security remedies can be applied in a timely manner. The key to being able to pull useful information from firewall log data is to summarize that data as it is produced. Summarized log data produces smaller data sets which helps lower the storage requirements and allows security administrators to more quickly query and react to the information.

FIG. **1** is a block diagram of an exemplary network **100**, in which an embodiment of the present invention may be implemented. The network **100** comprises an intranet **105** coupled to an Internet **110** via a router **150**. The intranet **105** comprises a firewall **111**, Unix servers **115**, NT servers **120**, a workstation **125**, a PC **130**, a security management station **135**, a network management station **140**, and a security server **145**. According to the present invention, intranet **105** may comprise alternative combinations of the elements illustrated, or may comprise less or additional devices (not shown). For example, the network **100** may not comprise Unix servers **115**, or may comprise a plurality of PCs **130** or workstations **125**. The firewall **111** may be any type of vendor specific firewall, such as a Cisco PIX or NetScreen firewall. Similarly, router **150** may be any type of vendor-specific router. Typically in operation, the firewall **111** receives messages from the Internet **110**, denies or accepts transmission of the messages based upon the firewall's security policy, and generates log messages (also referred to as log data) based upon responses to the received messages by the firewall **111**.

In one embodiment of the system illustrated in FIG. **1**, the security server **145** is a LogAppliance™ rack-mounted server, manufactured and sold by LogLogic, Inc. The security management station **135** manages operation and control of the security server **145**, and may request and display security reports via a security-Web browser. In one embodiment, the security server **145** is configured in hardware. However, the scope of the present invention comprises the implementation of the security server **145** in software or hardware. The security management station **135** typically executes security server driver software and security-Web browser software.

FIG. **2** illustrates an exemplary security platform **200**, according to one embodiment of the present invention. The security platform **200** may be implemented by the security server **145** (FIG. **1**) in hardware and/or software, and may be implemented by the security management station **135** in software. The security platform **200** comprises a message collection engine **205**, a data management engine **210**, and a data function engine **215**.

The data management engine **210** manages databases generated by the message collection engine **205** via optimization and data aging algorithms. For example, the data management engine **210** is configured to efficiently and quickly delete old data, manage large volumes of data, and optimize data compression and back-up routines.

The data function engine **215** may comprise platform components such as real time reporting, policy validation, trend and deviation analysis, security analysis, and application programming interfaces (APIs). For example, the data function engine **215** may process requests for a real-time log data report, a report compiled for a specified date or time interval, or a deviation analysis report based upon a comparison of log data to security policy procedures implemented by a given firewall.

FIG. **3** illustrates the message collection engine **205** of FIG. **2**, according to one embodiment of the present invention. The message collection engine **205** comprises a log receiver **320**, a parser **325**, and a database (DB) inserter **330**. The message collection engine **205** may comprise more or less components, or other components.

In operation, the log receiver **320**, in exemplary embodiments, receives log data from network security devices (not shown), such as Cisco PIX firewalls, routers, and NetScreen firewalls on a standard UDP port **514**. "UDP" is an abbreviation for User Datagram Protocol—a commonly-used protocol for information that requires no response, such as streaming audio and video. In addition, the log receiver **320** may receive Checkpoint log data on a TCP port **18184**. In alternative embodiments, the log receiver **320** may receive log data from any type of security device or vendor-specific firewall via any type of communication protocol. The log receiver **320** then processes the log data, and copies the log data to a first ring buffer **324**. The log receiver **320** may also copy the data to a last unapproved 100-buffer **321** (i.e., stores last 100 unapproved log messages), a last 100-buffer **322** (i.e., stores last 100 log messages), or a real-time viewer buffer **323**, based upon log data content and processes running in the security-browser window.

The log receiver **320** may also receive and store in memory (not shown) security policy information from the security devices. The log receiver **320** then compares the security policy information to the received log data to determine operational effectiveness of the security devices, and to initiate any changes to the security policy.

The exemplary parser **325** parses the log data received from the first ring buffer **324** to extract fields based upon log data message type, and generates Structured Query Language (SQL) statements from the extracted fields. The parser **325** then copies the SQL statements to a second ring buffer **326**. Subsequently, the DB inserter **330** inserts the SQL statements into database tables **331-336** in memory, according to the message type. In addition, the message collection engine **205** (FIG. **2**) summarizes the SQL statements stored in the database tables over various intervals of time, and copies the summarized SQL statements to tables stored on disk (not shown). The log receiver **320**, the parser **325**, and the DB inserter **330** will be discussed in more detail further below in conjunction with FIG. **5**.

FIG. **5** is an exemplary flowchart of method steps for parsing the log data as implemented by the message collection engine **205** of FIG. **3**, according to one embodiment of the present invention. In step **505**, the log receiver **320** (FIG. **3**) receives a log message from network security devices (e.g., firewall **111** and router **150** of FIG. **1**) on a UDP port **514** or a TCP port **18184**. Next, in step **510**, the log receiver **320** determines a data source of the log message, and compares the data source with a list of acceptable data sources. If the data source is on the list of acceptable data sources, and if the log receiver **320** determines that the data source is enabled and configured, then the log message is approved for parsing.

Next in step **515**, the log receiver **320** copies the log message to the first ring buffer **324** (FIG. **3**). The first ring buffer **324** is, in one embodiment, a first-in-first-out (FIFO) ring buffer that reduces a risk of losing log messages due to processing delays in the message collection engine **205**. Additionally, the log receiver **320** may optionally copy the approved log message to the real-time viewer buffer **323** (FIG. **3**). The real-time viewer buffer **323** stores log messages to be viewed in real-time. For example, a user of the security management station **135** (FIG. **1**) may open up a real-time view process (i.e., a window in a security browser) to view log messages received by the log receiver **320** in real-time. The real-time view process accesses the log messages stored in the real-time viewer buffer **323** for display via the security browser window.

Referring back to step **510**, if the log receiver **320** determines that the data source is not on the list of acceptable devices, or if the data source is enabled but not configured, then the log receiver **320** copies the log message to the last unapproved 100-buffer **321** or the last 100-buffer **322**. In one embodiment of the invention, the last unapproved 100-buffer **321** and the last 100-buffer **322** are 100-entry ring buffers. The user of the security management station **135** may further analyze the data stored in the 100-entry ring buffers for troubleshooting analysis purposes, for example. Alternative embodiments of these buffers **321**, **322**, and **323** may comprise other value entry ring buffers.

Next in step **520**, the parser **325** (FIG. **3**) reads a log message from the first ring buffer **324** (FIG. **3**). In one embodiment of the invention, the first ring buffer **324** is a FIFO ring buffer. Then in step **525**, the parser **325** extracts data fields from the log message, and converts the extracted data fields to an SQL statement. For example, in one embodiment of the present invention, the parser **325** searches the log message for predetermined keywords to identify message type. Once the message type is identified, the parser **325** utilizes a pre-determined function associated with the message type to extract the data fields. That is, the data fields are extracted by application of the pre-determined function to the log message.

In step **530**, the parser **325** copies the SQL statement to the second ring buffer **326**. In one embodiment of the invention, the second ring buffer **326** is a FIFO ring buffer. Next, in step **535**, a database (DB) inserter **330** (FIG. **3**) reads an SQL statement from the second ring buffer, and examines the SQL statement to determine a corresponding database table **331-336** (FIG. **3**). In step **540**, the DB inserter **330** inserts the SQL statement into the corresponding database table **331-336**. According to the present invention, database tables **331-336** may comprise an accept table **331**, a deny table **332**, a security table **333**, a system table **234**, a URL table **335**, and an FTP table **336**. In alternative embodiments, the present invention may comprise any combination of database tables **331-336** or other categories of database tables.

The second ring buffer **326** may advantageously receive database insert queries (e.g., SQL statements) from processes other than the parser **325**. That is, the second ring buffer **326** is configured to receive database insert queries from multiple processes, thus providing for a scalable parsing routine. Furthermore, the second ring buffer may store the received database insert queries in a queue, thus reducing a risk of losing data before the data is inserted into the appropriate database tables **331-336** via the DB inserter **330**. In addition, the present invention utilizes a single database connection (i.e., the DB inserter **330**) to execute insertion statements against the database tables **331-336**, thus providing a single controlled entry point to the database tables **331-336**. Thus, the DB inserter **330** streamlines insertion of data from multiple sources into the database tables **331-336**, reducing I/O conflicts and processing delays.

In exemplary embodiments, the DB inserter **330** copies approximately 99% of the SQL statements to the accept and the deny database tables **331** and **332**, respectively. The SQL statement is sent to the deny database table **332** when the SQL statement's corresponding log message received by the network security device (e.g., firewall **111**) is denied based on the network security device's policy list. Conversely, if a message received by the network security device is not denied, then the message is accepted. If the accepted message is a system message related to the security device's activity (e.g., number of connections passing through the security device), then the corresponding SQL statement is copied to the system database table **334**. However, if the accepted message relates to a network user accessing a particular URL site, then the corresponding SQL statement is copied to the URL database table **335**. Further, if the accepted message relates to a network user requesting a file transfer protocol (FTP) service, then the corresponding SQL statement is copied to the FTP database table **336**. According to one embodiment, should the database inserter **330** determine that the accepted message does not belong to system **334**, URL **335**, FTP **336**, or security **333** database tables, then the database inserter copies the SQL statement to the accept database table **331**. The present invention may comprise any number of database tables.

Next, in step **545**, the message collection engine **205** (FIG. **2**) reads the SQL statements from the accept and deny database tables **331** and **332**, summarizes the statements over one or more predetermined time intervals, and copies the summarized statements to tables on disk (not shown). Step **545** is described in more detail below.

The message collection engine **205** may comprise other components that parse log messages received from external security devices to generate SQL statements that are stored in database tables.

The data management engine **210** manages databases and data generated by the message collection engine **205** via summarization, aggregation, optimization and data aging algorithms. For example, the data management engine **210** is configured to manage large volumes of data, efficiently and quickly delete old data, and optimize data compression and back-up routines. The data management engine **210** will be discussed in more detail in connection with FIG. **4**.

FIG. **4** illustrates the data management engine **210** of FIG. **2**, according to one embodiment of the present invention. The data management engine **210** comprises a summarizer **420**, an aggregator **425**, a database (DB) inserter **430**, and a scheduler **440**. The data management engine **210** may comprise more or less components, or other components. In addition, FIG. **4** illustrates an accept database table **445**, a deny database table **450**, and a HEAP table (i.e., memory table) **455** stored in memory (not shown) of the security server **145** (FIG. **1**) or the security management station **135** (FIG. **1**). Furthermore, FIG. **4** illustrates a fine-grained deny table **460**, 1-hour accept tables **465**, 24-hour accept tables **470**, and 24-hour deny tables **475** stored on a system disc (not shown) coupled to the either the security server **145** or the security management station **135**, or both. In alternative embodiments of the invention, the tables **465**, **470**, and **475** may be configured to store data over other periods of time (e.g., 10-minute accept tables to 30-day accept and deny tables). In one embodiment of the invention, the fine-grained deny table **460** stores data for thirty days. That is, the data management engine deletes any data over thirty days old from the fine-grained deny table **460**.

In one embodiment of the invention, the scheduler **440** controls and manages operation of the summarizer **420**, the aggregator **425**, and the DB inserter **430**. Furthermore, the scheduler **440** (or another process of the security platform **200**) may continuously copy SQL statements from the accept database table **445** to the HEAP table **455**, and SQL statements from the deny database table **450** to the fine-grained deny table **460**. According to one embodiment, the HEAP table **455** buffers the accept SQL statements for 10 minutes. Alternative embodiments may use different time intervals. The scheduler also instructs the summarizer **420** and the aggregator **425** to summarize and aggregate, respectively, the SQL statements stored in the HEAP table **455** and the fine-grained deny table **460** over various intervals of time. The data management engine **210** then copies the summarized and aggregated SQL statements to tables **465**, **470**, and **475** stored on the system disk. In alternative embodiments, the data management engine **210** copies the summarized and aggregated SQL statements to tables **465**, **470**, and **475** stored on a distributed disk system (not shown). The summarizer **420**, the aggregator **425**, the DB inserter **430**, and the scheduler **440** will be discussed in more detail further below in conjunction with FIGS. **6** through **9**, inclusive.

FIG. **6** is an exemplary flowchart of method steps for summarizing the log data stored in the accept database table **445** (FIG. **4**) as implemented by the data management engine **210** (FIG. **4**), according to one embodiment of the present invention. In the exemplary embodiment, a CPU (not shown) of the security management station **135** (FIG. **1**) executes instructions corresponding to processes launched by the security-Web browser software. For example, the CPU executes the scheduler **440** (FIG. **4**) that manages, controls, and initiates other processes of the message collection engine for summarizing the log data.

In step **605**, the data management engine **210** creates the HEAP table **455** (FIG. **4**) in local memory of security management station **135** or local memory of the security server **145** (FIG. **1**). In one embodiment of the invention, the HEAP table is a pre-table created in random access memory (RAM) with a lifetime of n seconds. According to one embodiment of the present invention, n is a pre-determined variable with a range of 10-600 seconds. That is, every n seconds, the scheduler **440** deletes the HEAP table **455** and creates a new HEAP table (not shown). Next, in step **610**, the data management engine **210** initiates a process that continuously copies SQL statements stored in the accept database table **445** to the HEAP table **455**.

Then, in step **615**, the scheduler **440** instructs the summarizer **420** to summarize the SQL statements stored in the HEAP table over the n second interval to generate a fine-grained accept data chunk. According to the present invention, the summarizer **440** determines those SQL statements that share a commonality of one or more predetermined fields, and combines (i.e., condenses) those statements into a smaller number of statements or messages. For example, a SQL statement may include the following fields: a source IP, a source port, a destination IP, and a destination port. Typically, for every connection to the firewall **111** (FIG. **1**), the firewall **111** generates a log messages that comprises a source port number that has no significant security meaning. Therefore, if a user of network **100** (FIG. **1**) connects with a single Web server that initiates 50 connections to the firewall, for example, then the firewall **111** generates 50 log messages, each perhaps with a different source port number. However, each of the 50 messages has identical source IP, destination IP, and destination port numbers, because the user is connected to the single Web server.

Accordingly, in one embodiment of the present invention, the summarizer **420** determines which sets of SQL statements have identical source IP, destination IP, and destination port numbers, irrespective of the source port numbers of the SQL statements. The summarizer **420** then creates a new statement (i.e., message) generated from the 50 messages, for example. The summarizer **420** may repeat the above summarization process over the SQL statements stored in the HEAP table **455** for other fields of commonality to create other new condensed statements. Thus, in one embodiment of the invention, the summarizer creates a fine-grained accept data chunk comprising a condensation of the SQL statements stored in the HEAP table, based upon predefined fields of commonality (e.g., source IP, destination IP, and destination port numbers) and one or more fields of uniqueness (e.g., source port number).

In addition, the summarizer **420** may also summarize integer fields associated with the SQL statements stored in the HEAP table **455**, such as number of in-bytes (bytes flowing through the firewall **111** from the Internet **105** (FIG. **1**) to the intranet **110** (FIG. **1**)), number of out-bytes (bytes flowing through the firewall **111** from the intranet **110** to the Internet **105**), and number of messages passing through the firewall **111**.

Next, in step **620**, the data management engine **210** copies the fine-grained accept data chunk to a 1-hour accept table **465** stored on the system disk (not shown). In step **625**, the data management engine **210** deletes the HEAP table and creates a new HEAP table in local memory. Next, in step **630**, the data management engine **210** determines if the 1-hour accept table is full. For example, if n=600 s (i.e., 10 minutes), then the 1-hour accept table may comprise up to six fine-grained accept data chunks, since each fine-grained accept data chunk comprises a ten minute summary of SQL statements. According to the present invention, the 1-hour accept data table may comprise up to 3600/n fine-grained accept data chunks.

If, in step **630**, the data management engine **210** determines that the 1-hour accept table is not full (i.e., the 1-hour accept table comprises less than 3600/n fine-grained accept data chunks), then the method continues at step **610**. However, if the data management engine **210** determines that the 1-hour accept table is full (i.e., the 1-hour accept table comprises 3600/n fine-grained accept data chunks), then in step **635**, the scheduler **440** instructs the aggregator **425** to aggregate (i.e., perform a second summarization on) the fine-grained accept data chunks stored in the 1-hour accept table to generate a coarse-grained accept data chunk. According to the present embodiment, the coarse-grained accept data chunk comprises a one-hour period of data. Alternative embodiments of the invention may comprise coarse-grained data chunks with other time periods. Next, in step **640**, the data management engine **210** sends the coarse-grained accept data chunk to the DB inserter **430** (FIG. **4**), and the DB inserter **430** inserts the coarse-grained accept data chunk into a 24-hour accept table **470** stored on the system disk.

Next, in step **645**, the data management engine **210** creates another 1-hour accept table **465**, and in step **650**, determines if the 24-hour accept table **470** comprises twenty-four coarse-grained accept data chunks (i.e., if the 24-hour accept table **470** is full). However, if the 24-hour accept table **470** is not full, then the method continues at step **610**. When the 24-hour accept table **470** is full, the data management engine **210** determines whether a predetermined data storage threshold is exceeded. According to one embodiment of the present invention, the data storage threshold is a maximum amount of disk storage space allotted for storage of 1-hour accept tables **465**, 24-hour accept tables **470**, 24-hour deny tables **475**, and fine-grained deny tables **460**. If in step **635**, the data management engine **210** determines that the data storage threshold is not exceeded, then in step **660**, the data management engine **210** creates a new 24-hour accept table **470**, and the method continues at step **610**. However, if the data management engine **210** determines that the data storage threshold is exceeded, the data management engine **210** executes database management procedures in step **665**.

In exemplary embodiments of the invention, the data management engine **210** may execute database management procedures such as deletion of tables **460**, **465**, **470**, and **475** with specific creation dates, issuance of user notifications to initiate data-backup procedures, or initiation of data compression schemes to free-up disk space. In one embodiment of the invention, the data management engine **210** uses the "merge table" feature in MySQL that allows data management processes to view tables **460**, **465**, **470**, and **475** with identical schemas as a single parent table (not shown). That is, the parent table is a table of pointers that allows data management processes to efficiently manage large sets of tables comprising large amounts of data, and to: (1) delete old data quickly; (2) allow for efficient compression of selected tables; and, (3) allow for efficient back-up of selected tables to other storage devices.

FIG. **7** is an exemplary flowchart of method steps for summarizing the log data stored in the accept database table **445** (FIG. **4**) as implemented by the data management engine **210** (FIG. **4**), according to another embodiment of the present invention. In step **772**, the scheduler **440** (FIG. **4**) instructs the summarizer **420** (FIG. **4**) to summarize SQL statements stored in the HEAP table **455** (FIG. **4**) into single 10-minute data chunks after every 10-minute interval of time. In alternative embodiments, the summarizer **420** summarizes SQL statements stored in the HEAP table **455** over other predefined intervals of time.

Furthermore, in steps **774** and **776**, the scheduler **440** instructs the aggregator **425** to aggregate the 10-minute data chunks into a single 1-hour data chunk after every 1-hour interval of time. Then in optional steps **778** and **780**, the scheduler **440** may instruct the aggregator **425** to aggregate the 1-hour data chunks into a single 24-hour data chunk after every 24-hour interval of time. In step **782**, the scheduler **440** may then instruct the aggregator **425** to aggregate the data chunks over larger intervals of time. In the FIG. **7** embodiment of the invention, the summarizer **420** and aggregator **425** are instructed to summarize and aggregate data chunks based upon elapsed intervals of time.

FIG. **8** is an exemplary flowchart of method steps for aggregating log data stored in the deny database table **450** (FIG. **4**) as implemented by the data management engine **210** (FIG. **4**), according to one embodiment of the present invention.

In step **805**, the data management engine **210** initiates a process that continuously copies each SQL statement stored in the deny database table **450** to a fine-grained deny table **460** stored on the system disk. Next, in step **810**, the scheduler **440** instructs the aggregator **425** to aggregate (i.e., summarize) the SQL statements stored in the fine-grained deny table **460** over a one-hour time interval to generate a coarse-grained deny data chunk for the one-hour time interval. Then, in step **815**, the data management engine **210** sends the coarse-grained deny data chunk to the DB inserter **430** (FIG. **4**), and the DB inserter **430** inserts the coarse-grained deny data chunk into a 24-hour deny table **475** stored on the system disk.

Next, in step **820**, the data management engine **210** determines if the 24-hour deny table **475** comprises 24 coarse-grained deny data chunks (i.e., if the 24-hour deny table **475** is full). However, if the 24-hour deny table **475** is not full, then the method continues at step **810**. When the 24-hour deny table **475** is full, then the data management engine **210** determines whether the predetermined data storage threshold is exceeded in step **825**. If the data management engine **210** determines that the data storage threshold is not exceeded, then in step **830**, the data management engine **210** creates a new 24-hour deny table, and the method continues at step **810**. However, if the data management engine **210** determines that the data storage threshold is exceeded, the data management engine **210** initiates database management procedures in step **835**, and the method continues at step **830**. Step **835** is similar to step **665** (FIG. **6**), and is not discussed further.

FIG. **9** is an exemplary flowchart of method steps for summarizing the log data stored in the deny database table **450** (FIG. **4**) as implemented by the data management engine **210** (FIG. **4**), according to another embodiment of the present invention. In step **942**, the scheduler **440** (FIG. **4**) instructs the aggregator **425** (FIG. **4**) to aggregate SQL statements stored in the fine-grained deny table **460** (FIG. **4**) into single 1-hour data chunks after every 1-hour interval of time. In alternative embodiments, the aggregator **425** aggregates SQL statements stored in the fine-grained deny table **460** over other predefined intervals of time.

Then in optional steps **944** and **946**, the scheduler **440** may instruct the aggregator **425** to aggregate the 1-hour data chunks into a single 24-hour data chunk after every 24-hour interval of time. In step **948**, the scheduler **440** may then instruct the aggregator **425** to aggregate the data chunks over larger intervals of time. In the FIG. **9** embodiment of the invention, the aggregator **425** is instructed to aggregate data chunks based upon elapsed intervals of time.

The data management engine **210** (FIG. **4**) of the present invention summarizes and aggregates large amounts of data comprising log messages, and generates smaller amounts of data comprising summarized and aggregated deny and accept log messages stored in 24-hour accept and deny tables, and 1-hour accept tables on a system disk. The data management engine **210** of the present invention allows for efficient storage of data to disk, and quick and efficient retrieval of disk data, compression of disk data, deletion of disk data, and back-up of disk data to other data storage devices. In addition, the present invention allows a user to search the fine-grained deny table **460** (FIG. **4**) for a more detailed description of an event stored in the 24-hour deny tables **475** (FIG. **4**).

Example I

Parsing Log Data

Firewall log files are traditionally text strings of messages describing all the firewall activities. These messages can be categorized into accepted messages, denied messages, security event messages, and firewall system messages. Once categorized, each message can subsequently be broken down or parsed into its essential information. A portion of a log file from a Cisco PIX firewall is reproduced in Table I.

TABLE I

1	%PIX-6-302015: Built outbound UDP connection 10683 for outside: 207.69.188.185/53 (207.69.188.185/53) to inside: 192.168.1.100/1045 (24.145.191.42/2710)
2	%PIX-6-302016: Teardown UDP connection 10683 for outside:207.69.188.185/53 to inside: 192.168.1.100/1045 duration 0:00:01 bytes 384
3	%PIX-6-305011: Built dynamic TCP translation from inside:192.168.1.100/2577 to outside:24.145.191.42/9006
4	%PIX-6-302013: Built outbound TCP connection 10684 for outside: 193.108.95.49/80 (193.108.95.49/80) to inside: 192.168.1.100/2577 (24.145.191.42/9006)
5	%PIX-5-304001: 192.168.1.100 Accessed URL 193.108.95.49:/f/1917/8668/6H/espn.go.com/insertfiles/css/sportindex.css
6	%PIX-6-302015: Built outbound UDP connection 10685 for outside:207.69.188.185/53 (207.69.188.185/53) to inside:192.168.1.100/1045 (24.145.191.42/2710)
7	%PIX-6-302016: Teardown UDP connection 10685 for outside:207.69.188.185/53 to inside:192.168.1.100/1045 duration 0:00:01 bytes 186
8	%PIX-6-305011: Built dynamic TCP translation from inside:192.168.1.100/2578 to outside:24.145.191.42/9007
9	%PIX-6-302013: Built outbound TCP connection 10686 for outside:199.181.132.157/80 (199.181.132.157/80) to inside:192.168.1.100/2578 (24.145.191.42/9007)

A first step in organizing log data may be to parse the text strings into categories or fields that make up the message text. For example the first message in Table I can be parsed into the following fields:

Message code=% PIX-6-302015 (which means build outbound UDP connection)
Connection=10683
Source IP=192.168.1.100
Source port=1045
Destination IP=207.69.188.185
Destination port=53
NAT IP=24.145.191.42
NAT port=2710

Once the message is parsed into its fields, it may be advantageous to store the data in compressed form, for example, compressed integer form, in a database table for later queries. This process can reduce the storage requirements of each text message to less than 25% of its original size.

Summarizing the Parsed Data

In one exemplary situation, if a firewall is logging all messages, without filtering of messages, then the vast majority, usually over 80%, of the messages will likely be based on accepted TCP and UDP connections. To illustrate this point if a PC on the inside of a firewall opens up its browser to a typical web site and goes through a firewall, that firewall may produce 40 TCP built messages and 40 TCP teardown messages for a total of 80 log messages based on that one web page. If the firewall is doing network address translation, then that firewall will produce an additional 40 translate messages for that web page.

TCP build and teardown messages have similar formats that may include the following information: message codes, Source IP address, Source port number, Destination IP address, Destination port number, and number of bytes in the connection.

Referring again to Table I, it can be seen that messages **1**, **2**, **6** and **7** share the same Source IP (192.168.1.100), Destination IP (207.69.188.185), and Destination port (**53**). These messages indicate that the internal PC with an IP address of 192.168.1.100 is querying an external domain name server with an IP address of 207.69.168.185 for a host address.

Since all of the messages in Table I occurred in the same minute, in most cases it would be a waste of storage space to save all four messages. Those four messages can be summarized into the following:

Message code=Accepted
Message number=4
Source IP=192.168.1.100
Destination IP=207.69.188.185
Destination port=53
NAT IP=24.145.191.42

By using a combination of parsing and summarization techniques, the dataset of the log files can typically be reduced to less than 5% of the original message text. The benefits of this reduction in the dataset are not limited to storage capacity reduction, it also speeds up the backend processing for report generation. By working with a dataset less than 5% of its original size, queries against that dataset will benefit by not having to search through extra data.

The present invention has been described above with reference to exemplary embodiments. Other embodiments will be apparent to those skilled in the art in light of this disclosure. Furthermore, the present invention may readily be implemented using configurations other than those described in the exemplary embodiments above. Therefore, these and other variations upon the exemplary embodiments are covered by the claims of the present invention.

What is claimed is:

1. A method performed by a data processing system, comprising:
receiving raw log data from one or more log producing devices;
generating database statements from data fields extracted from the raw log data;
creating a first database table for storing the database statements, including designating a lifetime of the first database table such that when the lifetime of the first database table expires, a replacement first database table is created;
at an interval that corresponds to the lifetime, summarizing the database statements stored in the first database table into a data chunk that includes summary database statements, including:
identifying database statements stored in the first database table that share at least one common data field; and
combining the identified database statements into the summary database statements; and
storing, on a storage device, the summarized database statements as log files of the one or more log producing devices.

2. The method of claim **1**, comprising:
determining a data source of the raw log data; and
comparing the data source with a list of acceptable data sources before generating the one or more database statements.

3. The method of claim **1**, wherein generating the one or more database statements comprises:
searching the raw log data for a predetermined keyword to identify a message type; and
extracting the data field from the raw log data according to the message type.

4. The method of claim **1**, wherein the at least one common data field includes a data field of a source Internet protocol (IP) address, a destination IP address or a destination port number.

5. The method of claim **1**, wherein the summarized database statements as log files comprises:
storing the data chunk in a second database table that is associated with a first time period; and
periodically aggregating data chunks in the second database table to a third database table that is associated with a second time period that is longer than the first time period, including generating data that have coarser granularity than data in the data chunk.

6. The method of claim **5**, wherein:
the first database table includes a database table stored in memory, and
each of the second and third database tables includes at least one of an accept table or a deny table stored on disk.

7. Computer instructions stored on a non-transitory medium, the computer instructions configured to cause a data processing system to perform operations comprising:
receiving raw log data from one or more log producing devices;
generating database statements from data fields extracted from the raw log data;
creating a first database table for storing the database statements, including designating a lifetime of the first database table such that when the lifetime of the first database table expires, a replacement first database table is created;
at an interval that corresponds to the lifetime, summarizing the database statements stored in the first database table into a data chunk that includes summary database statements, including:
identifying database statements stored in the first database table that share at least one common data field; and
combining the identified database statements into the summary database statements; and
storing, on a storage device, the summarized database statements as log files of the one or more log producing devices.

8. The computer instructions of claim **7**, the operations comprising:
determining a data source of the raw log data; and
comparing the data source with a list of acceptable data sources before generating the one or more database statements.

9. The computer instructions of claim **7**, wherein generating the one or more database statements comprises:
searching the raw log data for a predetermined keyword to identify a message type; and
extracting the data field from the raw log data according to the message type.

10. The computer instructions of claim **7**, wherein the at least one common data field includes a data field of a source Internet protocol (IP) address, a destination IP address or a destination port number.

11. The computer instructions of claim **7**, wherein the summarized database statements as log files comprises:
storing the data chunk in a second database table that is associated with a first time period; and
periodically aggregating data chunks in the second database table to a third database table that is associated with a second time period that is longer than the first time period, including generating data that have coarser granularity than data in the data chunk.

12. The computer instructions of claim 11, wherein:

the first database table includes a database table stored in memory, and

each of the second and third database tables includes at least one of an accept table or a deny table stored on disk.

13. A system, comprising:

one or more security servers connected to one or more log producing devices through a local area network, the one or more security servers configured to perform operations comprising:

receiving raw log data from the one or more log producing devices;

generating database statements from data fields extracted from the raw log data;

creating a first database table for storing the database statements, including designating a lifetime of the first database table such that when the lifetime of the first database table expires, a replacement first database table is created;

at an interval that corresponds to the lifetime, summarizing the database statements stored in the first database table into a data chunk that includes summary database statements, including:

identifying database statements stored in the first database table that share at least one common data field; and

combining the identified database statements into the summary database statements; and

storing, on a storage device, the summarized database statements as log files of the one or more log producing devices.

14. The system of claim 13, the operations comprising:

determining a data source of the raw log data; and

comparing the data source with a list of acceptable data sources before generating the one or more database statements.

15. The system of claim 13, wherein generating the one or more database statements comprises:

searching the raw log data for a predetermined keyword to identify a message type; and

extracting the data field from the raw log data according to the message type.

16. The system of claim 13, wherein the at least one common data field includes a data field of a source Internet protocol (IP) address, a destination IP address or a destination port number.

17. The system of claim 13, wherein the summarized database statements as log files comprises:

storing the data chunk in a second database table that is associated with a first time period; and

periodically aggregating data chunks in the second database table to a third database table that is associated with a second time period that is longer than the first time period, including generating data that have coarser granularity than data in the data chunk.

18. The system of claim 17, wherein:

the first database table includes a database table stored in memory, and

each of the second and third database tables includes at least one of an accept table or a deny table stored on disk.

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